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2008 PACIFIC NORTHWEST



MANAGEMENT HANDBOOK

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Extension Services of Oregon State University, Washington State University, and University of Idaho.



Black spot on rose. Photo: Teresa Welch, Oregon State University.

2008 PACIFIC NORTHWEST

Plant Disease

MANAGEMENT HANDBOOK

Edited by Jay W. Pscheidt and Cynthia M. Ocamb

Extension Plant Pathology Specialists, Oregon State University

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Contents

Introduction	1	Alder (Alnus sp.)	
Acknowledgements	2	Alfalfa (Medicago sativa)	
Authors and Contributors		Alyssum	
Reviewers		Amaryllis (Hyppeastrum)	
		Amelanchier (Serviceberry)	80
History of the PNW Plant Disease Management Handbook		Andromeda (See Pieris)	
Disease Diagnosis and Control	4	Anemone (Japanese Anemone)	
Testing Services		Aphelandra	
Plant Disease Clinics		Apple (Malus sp.)	
OSU Plant Clinic Fees		Apricot (Prunus sp.)	
Specialized Identification Services		Arborvitae (<i>Platycladus</i> sp.)	93
OSU Central Analytical Laboratory	10	Arborvitae (<i>Thuja</i> sp.)	94
OSU-Hermiston — Plant Pathology Laboratory		Ash (Fraxinus sp.)	
Testing Services		Asparagus (Asparagus sp.)	96
Oregon Department of Agriculture Plant Health Laboratory		Aspen	97
WSU-Plant & Insect Diagnosis Laboratories		Azalea (<i>Rhododendron</i> sp.)	
Testing for Endophytes	12		99
Seed Testing for Phytopathogenic Bacteria		Bachelor's Button (See Centaurea cyanus) Barberry (Berberis sp.)	102
Tree Fruit Virus Testing and Therapy		Barley (Hordeum vulgare)	
Nematode Testing	13	Basil (Ocimum basilicum)	
Pathogens Common to Many Plants		Bean (Phaseolus vulgaris)	
Oregon's Most Unwanted: Invasive Species		Beet, Red (Beta vulgaris)	
Oregon Quarantines		Begonia	
Nematodes		Birch (Betula sp.)	
Weed Hosts of Root-lesion Nematodes		Blackberry (<i>Rubus</i> sp.)	
Diagnosis and Control of Phytophthora Diseases		Black Locust (Robinia sp.)	
Plants Susceptible to Phytophthora Diseases		Black Raspberry (See Raspberry)	120
APHIS Lists of Plants Regulated for <i>Phytophthora ramorum</i>		Blueberry (Vaccinium corymbosum)	128
APHIS Lists of Plants Associated with Phytophthora ramorum		Boston Ivy (Parthenocissus tricupidata)	
Powdery Mildew Diseases		Boxwood (Buxus sp.)	
Mycorrhiza		Boysenberry (See Blackberry)	
Damping-off in Tree Nurseries		Bracken Fern (Pteridium aquilinum)	138
Damping-off in Vegetable Seedlings		Broccoli (Brassica oleracea)	
Mycotoxins		Brussels Sprouts (Brassica oleracea)	
Plants Resistant or Susceptible to Armillaria Root Rot		Cabbage and Cauliflower (<i>Brassica</i> sp.)	
Hosts for Verticillium albo-atrum and V. dahliae		Caladium	
Plants Resistant or Susceptible to Verticillium Wilt		Calceolaria (Slipperwort)	
Plants Susceptible to Sclerotinia sclerotiorum		Calendula (Pot Marigold)	
Diseases Caused by Pseudomonas syringae		Calla Lily (Zantedeschia)	146
Crown Gall Diseases of Nursery Plants		Camellia	
Frequency of <i>Agrobacterium</i> Infection in Certain Hosts		Candytuft (Iberis sp.)	
Viruses and Viruslike Pathogens		Canola (See Rapeseed, also Cabbage and Cauliflower)	
Virus Groups Impatiens Necrotic Spot: New Name, Same Threat		Cantaloupe (Cucumis sp.)	
Virus Certification Program for Tree Fruit		Carnation (Dianthus caryophyllus)	
Parasitic Plants of Oregon		Carrot (Daucus carota)	153
Tree Decline		Catalpa	158
	50	Ceanothus	158
Nonpathogenic Phenomena	50	Cedar, Incense	159
Thatch in Home Lawns		Cedar	159
Algae, Lichens, and Mosses on Plants Care and Maintenance of Wood Shingle and Shake Roofs		Celery (Apium graveolens var. dulce)	
		Celosia (Cockscomb)	
Winter Injury of Landscape Plants in the Pacific Northwest Plant Nutrition Diagnosis		Centaurea cyanus (Bachelor's Button)	
Key to Nutrient Deficiencies in Vegetable Crops		Cherry (Prunus sp.)	
Key to Nutrient Deficiencies of Deciduous Fruit and Nuts		Cherry, Flowering	
•	/ 1	Chestnut (Castanea sp.)	178
Host and Disease Descriptions		Chickpea (Garbanzo Bean) (Cicer sp.)	178
Abies sp. (See Fir, True)		Christmas Trees (See Fir or Pine)	
Acer sp. (See Maple)	72	Chrysanthemum	179
African Violet (Saintpaulia sp.)		Cilantro (See Coriandrum)	
Ageratum		Cineraria	
Ailanthus (Tree of Heaven)		Clematis	
Λιυγά	/4	Clover (Trifolium sp.)	183

Coleus	186	Hoya	290
Columbine (Aquilegia)		Huckleberry (<i>Vaccinium</i> sp.)	
Coral Bells (Heuchera sp.)		Hyacinth (Hyacinthus orientalis)	
Coriandrum sp. (Coriander, Cilantro, Parsley)		Hydrangea	
Corn (Zea mays)		Hypericum (St. Johnswort)	
Cosmos	192	Impatiens	
Cotoneaster	193	Indian Hawthorn (Rhaphiolepis sp.)	293
Cottonwood (See Poplar)		Incense Cedar (See Cedar)	
Crabapple (Malus sp.)	193	Iris (Iris xiphioides and others)	293
Cranberry (Vaccinium macrocarpon)		Ivy (Hedera helix)	
Crape Myrtle (<i>Lagerstroemia</i> sp.)		Juniper (Juniperus sp.)	
Cucumber (Cucumis sativus)	201	Kalmia (Mountain Laurel)	
Currant (Ribes sp.) (See Gooseberry and Currant)		Kinnikinnick (Arctostaphylos uva-ursi)	
Cyclamen		Kiwifruit (Actinidia sp.)	
Cypress (Cupressus sp.)		Lantana	302
Daffodil (Narcissus sp.)	207	Larch (<i>Larix</i> sp.)	302
Dahlia		Larkspur (See Delphinium)	
Daphne		Lavendar	302
Daylily		Lawn and Turf	
Delphinium			
1	213	Leek (Allium porrum)	
Dewberry (See Blackberry)		Lettuce (Lactuca sativa)	
Dianthus (Sweet William)		Leucothoe	
Dieffenbachia		Lilac (Syringa vulgaris)	317
Dogwood (Cornus sp.)	217	Lily (<i>Lilium</i> sp.)	319
Dracaena	220	Lily, day (<i>Hemerocallis</i> spp.) (See Daylily)	
Dusty Miller (See Centaurea)		Lingonberry (Vaccinium vitis-idaea)	321
Eggplant (Solanum melongena)	220	Lobelia	
Elm (Ulmus sp.)		Locust (See Honey Locust or Black Locust)	522
Erica sp. (Heath)		Loganberry (See Blackberry)	222
Euonymus	223	Lupine (Lupinus sp.)	
Fern (See Bracken Fern)		Madrone (Arbutus menziesii)	
Filbert (See Hazelnut)		Magnolia	324
Fir (Pseudotsuga menziesii and Abies sp.)	224	Maple (<i>Acer</i> sp.)	324
Flax (Linum sp.)	234	Marigold (Tagetes sp.)	
Forget-me-not (Myosotis sp.)		Meadowfoam (Limnanthes alba)	
Forsythia		Mint (See Peppermint)	20
Foxglove (Digitalis spp.)			220
		Mock Orange (Philadelphus sp.)	
Fuchsia	230	Monarda sp. (Bee Balm)	
Garbanzo Bean (See Chickpea)		Mountain Ash (Sorbus aucuparia)	329
Garlic (Allium sativum)		Mountain Laurel (See Kalmia)	
Geranium (Pelargonium sp.)	239	Mulberry (Morus sp.)	330
Gerbera Daisy	243	Mushrooms (Many genera)	330
Ginseng (Panax sp.)	243	Muskmelon (See Cantaloupe)	
Gladiolus	246	Myrtlewood (Umbellularia californica)	331
Gloxinia		Narcissus (See Daffodil)	
Golden Chain (<i>Laburnum</i> sp.)		,	221
		Nasturtium	331
Gooseberry and Currant (Ribes sp.)		Nectarine (See Peach)	
Grape (Vitis sp.)	250	Oak (Quercus garryana)	
Grass for Lawn and Turf (See Lawn and Turf)		Oats (Avena sativa)	333
Grass for Seed	260	Onion (Allium cepa)	335
Greenhouse Plants, Ornamental	270	Orchid	341
Greenhouse Plants, Tomato	272	Oregon Grape (Mahonia aquifolium)	
Hawthorn (Crataegus sp.)		Otto Luyken (See Prunus laurocerasus)	
Hazelnut (Corylus avellana)		Oxalis	2.42
Heather (Calluna sp.)			
		Pachysandra	
Hebe		Palm	344
Helleborus		Parsley (See <i>Coriandrum</i> sp.)	
Helleborus niger (Christmas Rose)		Pansy (Viola sp.)	344
Hemlock (Tsuga sp.)	281	Pea (Pisum sativum)	
Holly (Ilex aquifolium)		Peach (Prunus sp.)	
Hollyhock (Alcea rosea)		Pear, Asian	
Honey Locust (Gleditsia sp.)		Pear (Pyrus sp.)	
Honeysuckle (Lonicera sp.)			
		Peony (Paeonia sp.)	
Hop (Humulus lupulus)		Pepper (Capsicum sp.)	
Horse-chestnut (Aesculus sp.)		Peppermint (Mentha sp.)	366
Horseradish (Armoracia rusticana)		Periwinkle (See Vinca)	
Hosta	289	Petunia (Petunia sp.)	370

Phlox	
Photinia	
Pieris (Andromeda)	
Pine (Pinus sp.)375	1
Plum (See Prune and Plum)	
Plum, Flowing	
Poinsettia (Euphorbia pulcherrima)379	
Poplar (Populus sp.)	
Port-Orford-cedar (Chamaecyparis lawsoniana)	
Potato (Solanum tuberosum)	
Primrose (<i>Primula</i> sp.)	
Privet (Ligustrum sp.)	
Prune and Plum (<i>Prunus</i> sp.) 402	
Prunus laurocerasus	1
Pumpkin (Cucurbita pepo) (See Squash)	
Pyracantha (Firethorn)	
Quince 407	
Radish (Raphanus sativus)	
Rapeseed (Brassica rapa and B. napus (= B. campestris))408	
Raspberry (Rubus sp.)410	1
Redbud (Cercis sp.) (See Maple)	
Rhododendron417	
Rhubarb (Rheum rhabarbarum)423	
Rose (Rosa sp. and hybrids)	
Rudbeckia sp. (Black-eyed Susan)432	,
Rutabaga (See Turnip and Rutabaga)	
Sage (Salvia sp.)432	,
St. Johnswort (See Hypericum)	
Saintpaulia (See African Violet)	
Salal (Gaultheria shallon)433	
Salvia (See Sage)	
Schlefflera	
Schizanthus (Butterfly Flower)433	
Seed Crops, Crucifers	
Smoke Tree (Cotinus coggygria)435	
Snapdragon (Antirrhinum majus)	
Snowberry (Symphoricarpos sp.)438	
Soybean (Glycine max)438	,
Spearmint (See Peppermint)	
Spinach (Spinacia oleracea)438	
Spruce (Picea sp.)442	
Squash (Cucurbita sp.)443	
Statice (Limonium sp.)448	,
Stock (Matthiola sp.)449)
Strawberry (Fragaria sp.)449)
Sugar Beet (Beta vulgaris)455	,
Sunflower (Helianthus sp.)461	
Sweetpea (Lathyrus odoratus)461	
Swiss Chard (Beta vulgaris subsp. cicia)	
Sycamore (Platanus sp.)462	
Tanoak (Lithocarpus sp. and Lithocarpus densiflorus)463	j
Taxus sp. (See Port-Orford-cedar)	
Ternstroemia gymnanthera464	
Tomato (Lycopersicon esculentum)464	
Tulip472	
Tulip Tree (Liriodendron tulipifera)474	
Turf Diseases (See Lawn and Turf)	
Turnip and Rutabaga474	ļ
Verbena475	
Viburnum476	
Vinca (Periwinkle)	
Walnut (Juglans sp.)478	
Watermelon (Citrullus sp.)	
Weeping Fig (Ficus benjamina)	
Wheat (Triticum aestivum)	
Willow (Salix sp.)495	
-	

Yew (See Port-Orford-cedar)	
Youngberry (See Blackberry and Raspberry)	100
YuccaZelcova (See Crabapple)	
Zinnia	496
Zucchini (See Squash) Zygopetalum	408
Pesticides for Disease Control	
Fungicides, Bactericides, and Nematicides	
Biofungicides and Plant Activators Registered in Oregon	
Materials Allowed for Organic Disease Management	
Fungicide Theory of Use and Mode of Action	
Fungicide Resistance and Fungicide Families	
Fungicide Families (Table)	525
Seed Treatments	
Vegetable Seed Treatment	
Barley, Oat, Rye, Triticale, and Wheat Seed Treatments	527
Fungicide Effectiveness as Seed Treatments	
for Cereal Diseases	
Fungicides for Disease Control in the Home Landscape	530
Fungicide and Pollen Interactions	532
Agricultural Spray Adjuvants	
Spray-tank Adjuvants	533
Horticultural Spray Oils	
Improving Spray Efficiency	
Preparing Tank-mix Bordeaux Mixture	
Limes in Sprays for Disease Control	
Orchard Soil Fumigation	
Tree Wound Paints	
Fumigating Soils for Nematode Control	
Using Pesticides Safely	
What to Do in Case of Pesticide Poisoning	
Spills and Cleanup	
Cleaning, Recycling, and Disposing of Agricultural Pesticide Containers	
Pesticides and Water Quality	
Pesticides, Endangered Species, and Mandatory No-Spray	
Buffer Zones	547
Special Pesticide Registration Options	548
Additional Pesticide Information	549
Website Information	549
Regulatory Authorities	
Worker Protection Standards for Agricultural Pesticides	550
Educational Requirements under the Worker Protection	
Standard	551
Restricted-entry Intervals and Early-entry Work Situations	
for Workers and Handlers	
Personal Protective Equipment Definitions	553
Minimum Personal Protective Equipment and	550
Work Clothing for Handling Activities Organophosphate and Carbamat Pesticide Poisoning and	
Cholinesterase Monitoring	555
How to Reduce Bee Poisoning from Pesticides	
Pesticide Application Records	
Glossary	
Useful Tables	
Index	590

Introduction

This handbook is intended as a ready reference guide to the control and management tactics for the more important plant diseases in the Pacific Northwest. No attempt has been made to include all of the plant diseases that could possibly occur in the Pacific Northwest. The specific cultural, biological, and chemical recommendations are intended to manage a specific plant disease but may not always be appropriate under all production circumstances. The synthesis of a specific management recommendation should be done by a qualified individual. For this reason, this book should be used by—and has been expressly written for—county Extension agents, consultants, field and nursery people, and chemical industry representatives.

Growers also will find this publication useful but should contact their local county Extension agent or consultant for specific recommendations. Management of plant diseases is based first on an accurate diagnosis since plant problems can be due to environmental, physiologic, entomological or management problems, as well as plant pathogens or a combination of these problems. Organic growers will concentrate on cultural and biological control measures but should realize that many compounds listed under chemical control are "natural"—that is, not synthetically produced—and/or are permitted for organic production. These products are signified with an \Box and are based on the National Organic Standards of allowed substances for plant disease control (Subpart G – Administrative 205.601). Please check with your local certifying agency to verify what is allowed or regulated.

Master gardeners and homeowners may find this publication useful. However, many of the compounds listed under chemical control are available only to licensed applicators. Compounds generally recognized as safe can easily be obtained at local garden centers and supply stores. Some of these materials in the "Host and Disease Descriptions" section of this book are represented by the symbol \mathbb{H} . This symbol simply indicates that the same product or a similar product with the same active ingredient is commonly available in home packaging.

Chemical control recommendations are based on information available in December of the year preceding the year given on the cover of the handbook. Legal uses of many pesticides are changing continually. Changes may include de-listing a crop or site, different formulations that require different application rates, new restrictions on preharvest applications or reentry periods, and unique circumstances. Therefore, always read the current label before using any product.

Although we have an extensive and useful index in the back of this book we are unable to create an index for all aspects of this book. Readers might find it more useful to do an electronic or computer search of this book. Please go to our web site to conduct very powerful and easy search for any word of your choice. For example, pesticides are not indexed but could easily be found using the computer search engine. The web site can found at http://plant-disease.ippc.orst.edu/. Several color photographs of disease symptoms can also be found at this site.

Information in this publication is in a state of constant change. New information is added and existing information is updated. With so many changes and people involved, there is always the possibility of error. We appreciate being informed of any errors that you may detect. Suggestions for improvement are welcome, also. We have worked to make this book responsive to the needs of the people who use it and will continue to strive for that in the future.

JAY W. PSCHEIDT and CYNTHIA M. OCAMB

The information herein is supplied with the understanding that no discrimination is intended and that listing of commercial products, necessary to this handbook, implies no endorsement by the authors or the Extension Services of Oregon, Washington, or Idaho. Criticism of products or equipment not listed is not implied or intended.

Due to continually changing laws and regulations, the Extension Services can assume no liability for the suggested use of chemicals contained herein. Pesticides should be applied according to the label directions on the pesticide container.

Disease Diagnosis and Control

J.W. PSCHEIDT, Extension Plant Pathology Specialist, OSU

Someone who has a plant problem asks two questions: What is the problem, and how do I correct it? These are hard questions for beginners and experts alike. Diagnosis is the process of determining the cause of a problem. It can be a long or short process depending on one's ability and the nature of the problem. Once the cause is known, an appropriate control strategy can be developed.

Disease Diagnosis

Plant pathologists take many different approaches to diagnosing plant disease problems. The first step is to decide whether the problem *is* a plant disease. The broadest definition of plant disease includes anything that adversely affects plant health. This definition can include such factors as nutrient deficiencies, lawnmower damage, air pollution, and pathogens. A stricter definition usually includes a persistent irritation resulting in plant damage. This excludes mechanical damage such as lawnmower injury to trees or natural events such as hail or lightning. A very strict definition includes only those (living) things that replicate themselves and spread to adjacent plants. This includes such biological organisms as nematodes, fungi, bacteria, and viruses. Plants damaged by macroscopic organisms, such as deer, rodents, and birds usually are not considered to be diseased.

Many novices use the picture-book method of diagnosis: looking at textbook pictures of problems and attempting to match the problem with the picture. "The Ortho Problem Solver" and the APS Plant Disease Compendia series are examples of texts that have many useful, high-quality color pictures. Although this method is useful for simple and common problems, it is usually inefficient and inaccurate for more complex or difficult problems.

Another simple technique, used by "The Ortho Problem Solver," is the checklist. Through a series of 70 questions, a person builds a case history of the problem. The questions include the kind, age, and size of the plant. The plant's location, location of the property, and relationship to other plants also are part of the checklist. Information on the recent weather and soil conditions, soil coverings, and recent care also are needed. Describing the overall condition of the plant is very important.

Symptoms and signs are used to diagnose the condition of a plant. *Symptoms* are the physical characteristics of disease expressed by the plant. Symptoms can include wilt, galls, cankers, rots, necrosis, chlorosis, and general decline. Definitions of these can be found in the glossary. *Signs* are physical evidence of the pathogen causing the disease. Signs can include fungal fruiting bodies (such as mushrooms or pycnidia), mycelia, bacterial slime, presence of nematodes or insects, or the presence of insect holes accompanied by sawdust or frass. Again, these terms are defined in the glossary.

The checklist approach is a good guide for the types of questions to ask, but not all the questions are necessary. Some pertain only to certain situations or plants. Other approaches to disease diagnosis attempt to narrow the possibilities with each question and are like synoptic or dichotomous keys.

The diagnostic keys differ depending on the author. Some keys start by identifying the part of the plant that is affected. Is it the whole plant, or just the leaves, branches, stems, or roots? Some refine the first questions to stages of the plant; for example, are

the seedlings, flowers, fruit, or seed affected? Some diseases affect only certain portions of a plant. Many other references start out with the plant itself: is it a cherry tree, foliage plant, or zinnia? Only a limited number of diseases attack a given plant species.

There is no one key set of questions or techniques for diagnosing plant diseases. Experience and practice are the best teachers. It is easier to diagnose plant problems by making a personal, on-site inspection. Subtle influences of the site, plant environment, and possible management practices can be seen that may have been overlooked by the grower. Difficulties arise when the diagnostician is presented only a portion of the plant because that portion may or may not indicate the real problem. The worst situation is a request for a diagnosis by phone, because misunderstandings and an inaccurate diagnosis can easily occur. However, sometimes this is the only contact someone may have with a diagnostician.

The Systematic Approach

To organize your approach to a plant disease problem, the "Systematic approach to diagnosing plant damage" by J. L. Green, O. Maloy, and J. Capizzi is useful and is presented briefly here. It consists of a detailed handout, a study guide, and a color slide set. It is designed as a Master Gardener seminar and is useful to hear or to present yourself.

The approach involves defining the real problem and distinguishing between living and nonliving causes of plant damage by looking for patterns, determining the development of the damage, and building a case history of the problem. With these steps, it is usually easy to narrow the possibilities and to turn to appropriate reference materials including textbooks, herbarium samples, and knowledgeable specialists.

Define the Real Problem

Identify the plant and what it should look like at this time of year. A grower or gardener may mistake a normal stage of development for a diseased plant. Describe the abnormality in terms of *symptoms* and *signs*. Although a plant may exhibit symptoms of wilting, the real problem may be due to rotted roots, a girdled trunk, or lack of water. Determine what part(s) of the plant is/are affected. The rest of the procedure involves distinguishing between living and nonliving factors.

Look for Uniform or Nonuniform Patterns

Uniform damage is indicative of nonliving factors. Damage may occur on many plant species in the same area, on all the plants in a particular row or block, on all the leaves or shoots on one side of the plant, or on the same-age portion of each leaf or needle. Nonuniform damage to plants is indicative of living factors such as pathogens or insects. This damage shows up as scattered affected plants among a community of plants, scattered leaves or shoots on a single plant, or scattered spots on a single leaf.

Determine the Time Development of the Damage

If damage does not spread or there is a clear line of demarcation between damaged and nondamaged tissues, this is indicative of nonliving factors. Spread of the damage from plant to plant or to other plant parts over time indicates damage by a living organism.

Testing Services

Plant Disease Clinics

Several plant disease clinics in the Pacific Northwest can help diagnose plant problems. Publicly supported clinics are listed below. A listing of other laboratories (mostly private) that provide a similar service can be found at:

http://wsprs.wsu.edu/AnalyticalLabsEB1578E.pdf
The list is "Analytical laboratories and consultants serving agriculture in the Pacific Northwest" (Publication EB1578E), compiled in 2003 and updated in 2005 by Catherine H. Daniels. Oregon's version is "Laboratories Serving Oregon: Soil, Water, Plant Tissue, and Feed Analysis" (EM 8677), last revised in June 06; online at http://extension.oregonstate.edu/catalog/html/EM/EM8677.html

For best service, for the most useful returns on your efforts, and for efficient use of our time, please read and observe these instructions before submitting specimens.

Collecting

- Select material showing the symptoms you are concerned about. Send several samples showing various stages of disease, especially early symptoms. If possible, also send a healthy plant.
- Get all parts of plants, including roots where practical.
 Enclose roots and soil in a plastic bag. Use another bag to enclose the rest of the plant.
- 3. If it is not practical to send the entire plant, include several affected portions of the plant. With stem or branch disorders, also include a section of live material attached to the diseased portion.
- 4. If a vascular wilt such as Verticillium wilt or Dutch elm disease is suspected, send several branch sections 1 inch in diameter and about 6 inches long from branches with dying, wilted, or yellowed leaves. Do not send dead wood. Put samples in a plastic bag to prevent drying.
- 5. Turfgrass samples should be taken from the edges of affected areas that include dying and also apparently healthy plants. Send one or two 3-by-3-inch squares of sod containing 1 inch of attached soil. Wrap each sample in one thickness of slightly dampened toweling, then in dry newspaper. Send as much information as possible.
- 6. Fleshy specimens such as mushrooms, fruit, or potatoes should be as firm as possible and show early and intermediate symptom development. Wrap specimens separately in paper towels or newspaper. Do not put in plastic. Pack with sufficient padding to avoid crushing.

Packing

- Keep plants cool and moist before shipping. Mail as soon as possible after collection. Mail specimens early in the week to avoid delay in the post office over weekends or holidays.
- Pack in a sturdy container to prevent crushing in transit. Use paper to pack the specimen firmly in the container.
- Identify package with labels both outside and inside. Put the label and the Plant Clinic Disease Form in a waterproof barrier such as plastic.

Addressing Packages

Oregon (from any location)

Plant Disease Clinic, Cordley Hall 1089, 2701 SW Campus Way, Oregon State University, Corvallis, OR 97331-2903 (Sample forms, fee information, directions to the Clinic, and other info about the OSU Plant Clinic is available at http://www.bcc.orst.edu/bpp/Plant Clinic/index.htm)

Oregon (Northeast Oregon and North Central only)

Extension Plant Pathology Laboratory, 2121 S. First, OSU, Hermiston, OR 97838.

Idaho

Plant Samples, Kimberly Research and Extension Center, Kimberly, ID 83341

Plant Samples, Parma Research and Extension Center, University of Idaho, Parma, ID 83660

Western Washington

WSU Puyallup Plant Clinic, 7612 Pioneer Way East, Puyallup, WA 98371-4998. (Fees required.)

British Columbia

Plant Diagnostic Laboratory, British Columbia Ministry of Agriculture, Fisheries, and Food, 1767 Angus Campbell Rd., Abbotsford, BC V3G 2M3 Canada (Fees required).

Information

Fill out the appropriate Plant Disease Form or Plant Disease Identification Request sheets with as much information as possible. These forms are available in your county Extension offices, the labs listed above and on the web at http://www.bcc.orst.edu/bpp/Plant%20disease%20form%202004.pdf. This information is valuable as an aid to diagnosis. Some labs will not process samples unless a form has been filled out. Photographs or even video tapes convey a lot of information that may be useful. The more information you provide, the more accurate the diagnosis will be.

OSU Plant Clinic Fees

Services and fees

Insect/mite and other arthropod identifications are currently provided free of charge.

Disease Diagnosis Services

Plant disease diagnosis = \$40.00 per sample.

This is our most frequently requested service. The service includes overall evaluation, including microscopic exam, leaf dip with an electron microscope or ELISA assay (for suspected virus infection), results from a moist chamber incubation, isolations onto artificial nutrient media, and identification of fungi or bacteria to genus. Viral inclusion analysis and measurement of soil pH and total soluble salts will be performed if necessary. Control recommendations are included.

Specialized Identification Services

Bacterial identifications

Identification of purified bacterial cultures = \$22.00

Pathogens Common to Many Plants

Oregon's Most Unwanted: Invasive Species

Invasive species are those plants, animals, and microbes not native to a region which, when introduced either accidentally or intentionally, out-compete native species for available resources, reproduce prolifically, and dominate regions and ecosystems. Because they often arrive in new areas unaccompanied by their native predators, invasive species can be difficult to control. Left unchecked, many of these organisms have the potential to transform entire ecosystems, as native species and those that depend on them for food, shelter, and habitat disappear.

The Oregon Invasive Species Council has developed a list of the 100 least wanted species. These organisms threaten to invade at any time and available information allows us to predict that they would have a serious negative economic or ecological impact if they were to become established in the state. Eradication should be seriously considered if incipient populations are found. The costs of eradication are likely to be much less than the impacts associated with permanent establishment. This list is updated annually.

The list is made up of micro-organisms, aquatic plants, land plants, aquatic invertebrates, land invertebrates, fish, birds and mammals. Only the plant parasitic ones are listed below:

Fungi

Alder root rot — *Phytophthora alni* — In 1993 a new collar-rot disease of European alders (*Alnus spp.*) was reported in the U.K. A *Phytophthora* was isolated and shown to comprise a swarm of hybrids between two *Phytophthora* species: *P. cambivora* and a *Phytophthora* close to *P. fragariae*. Both these 'parent' species were probably introduced into Europe. Neither is a pathogen of alder; i.e., the hybridization event may have led to a new host specificity. The event is probably recent and it has been suggested that it occurred in a nursery environment. The hybrids are now spreading across Europe, probably mainly via infested planting stock.

Oak wilt — Ceratocystis fagacearum — Oak wilt has been found in 21 States in the central part of North America. Oak wilt has also been reported in Texas—outside its main range. It was first recognized as an important disease in 1944 in Wisconsin where over half the oaks have been killed. In West Virginia where predominately oak forests cover 70 percent of the land area, oak wilt losses average less than one tree per square mile each year. No species of oak is known to be immune to this vascular disease. Plantation-grown Chinese chestnuts can also be naturally infected by the oak wilt fungus. Moreover, inoculation experiments have demonstrated that over 35 native and exotic oaks are susceptible, as well as American and European chestnuts, species of chinkapin, tanoak, and several varieties of apple.

Pear trellis rust — *Gymosporangium fuscum* — The disease affects pear and juniper, which is the alternate host of the fungus. The disease is established only in southern British Columbia and Contra Costa County, CA. It was found on pear in the Bellingham, WA area just south of the Canadian border in 1997.

Potato wart — *Synchytrium endobioticum* — A soil borne fungal parasite which is an obligate parasite of certain members of the order *Solanaceae* with potato (*Solanum tuberosum*) being the only cultivated host. In Mexico some wild *Solanum* species

are also known as hosts. Has been found in **Asia** (Bhutan, China, India, Lebanon, Nepal), **Africa** (Algeria, South Africa, Tunisia), Europe (All countries, except Portugal where it was eradicated), **North America** (Canada [NFLD], USA [eradicated], Mexico), **Pacific** (New Zealand's south island), and **South America** (Bolivia, Chile, Falkland Is., Peru, Uruguay). On October 24, 2000, the Canadian Food Inspection Agency (CFIA) confirmed the presence of potato wart disease in a single field in Prince Edward Island (P.E.I.) and took immediate steps to prevent its spread. This was the first occurrence of potato wart in an agricultural area outside of Newfoundland and Labrador, where a plant quarantine has been in place since 1912.

Ramorum canker and blight (Sudden Oak Death) -*Phytophthora ramorum* – A fungus-like organism first reported to cause leaf blight, stem canker, and tip dieback on nursery-grown rhododendrons and viburnums in Germany and the Netherlands in 1993. At about the same time, many tanoaks (Lithocarpus densiflorus), and oaks (Quercus sp.) in the San Francisco Bay Area were dying from this same disease. In Oregon, the fungus was found killing wild rhododendrons in a few isolated sites just north of Brookings, OR during the summer of 2001. Eradication of infected plants was initiated soon after the sites were found and continued when new infections were found. The infestation remains confined to isolated spots within a 9-square-mile quarantined area of forest land near Brookings. In the spring of 2003, the disease was discovered in a wholesale nursery in Oregon on Pieris, Viburnum, and Rhododendron and in Washington at a retail outlet affiliated with the Oregon nursery. These and near by host plants were destroyed. An international shipment of rhododendrons was suspected as the source of contamination for these nurseries. The host list for this organism includes 84 different plants in at least 12 plant families. This is a federally quarantined pathogen such that nurseries exporting hosts/associated hosts must participate in the federally mandated certification program to export product interstate and internationally.

Disease not yet named — Phytophthora kernoviae - A funguslike organism found only in England infecting Fagus sylvatica (beech), Rhododendron spp., Quercus robur (English oak), Quercus ilex (holm Oak), Gevuina avellana (Chilean hazelnut), Liriodendron tulipfera (tulip tree), Magnolia stellata, Michelia doltsopa and Pieris formosa. The organism was found during surveys for P. ramorum and has very similar symptoms on these hosts. It was found in both ornamental nurseries and plants in the landscape. There is little information for this recently discovered pathogen.

Bacteria and Similar Organisms

Hazelnut bacterial canker — Pseudomonas avellanae

(*P. syringae pv. coryi*)— The bacterium causes a hazelnut decline and is currently present in about 1,000 out of the 20,000 hectares of hazelnut orchards in central Italy. It has also been found in northern Greece. The main symptoms include the rapid wilting of twigs, branches and trees during spring and/or summer. Characteristically, the leaves remain attached to the twigs after their withering.

Diagnosis and Control of Phytophthora Diseases

J.W. PSCHEIDT, Extension Plant Pathology Specialist, OSU

The first step in controlling any of the several diseases caused by *Phytophthora* spp. is to obtain an accurate diagnosis. Although *Phytophthora* is a recognized disease problem in the Pacific North-west, it has been misdiagnosed half the time in Oregon. A wide variety of cultural and chemical controls can be implemented for *Phytophthora* problems. Time spent collecting all the information for an accurate diagnosis will aid control efforts in the long run.

Diagnosing a Phytophthora Problem

Certain lines of evidence can quickly lead you toward (or away from) a *Phytophthora* disease diagnosis. The evidence is in the field characteristics, field history, and symptoms of the affected plants. Knowing the biology of the *Phytophthora* fungus and conditions that favor its development also helps the diagnosis.^{2,3} Plant samples can also be taken to a laboratory for traditional or "high tech" tests to confirm the presence of this fungus-like organism.

Field Characteristics and History

The two main factors to look for when diagnosing *Phytophtho-ra*-caused plant problems are the pattern of diseased plants and water drainage. These factors can be observed in flat open areas, undulating fields, sloped nursery container yards, or even in the greenhouse. *Phytophthora* organisms are commonly referred to as water molds. They thrive, grow, reproduce, and infect plant roots in water, saturated soil, and along river banks and ponds. Flooded or saturated soils are not favorable to plant growth and can predispose plants to infection. Anywhere significant quantities of water collect, accumulate, or flow, *Phytophthora* spp. can be found.

Phytophthora diseases can be found on cranberries growing in low bogs near the coast or in the mountains on trees growing several thousand feet above sea level. The common factor in all cases is water. Excess water or poor drainage allows roots to become flooded for extended periods. During such events, this organism can produce a swimming spore (zoospores). Zoospores are attracted to the roots and begin the infection process.

Diseased plants generally are in the lower areas of a field, where excess rain or irrigation water drains off. Hill crests or steeply sloped areas are unlikely places to find *Phytophthora* diseases. A few exceptions include Phytophthora root rot problems on noble fir in Christmas tree plantations or Port-Orford-cedar forest trees. Diseased trees can be found in sites where water flows, either in naturally occurring ravines and ditches or along drainage from logging roads.

Puddled water or poor drainage can be in areas where growers think they have taken corrective measures. Container nurseries have used various means to collect and recycle excess water. Plastic-covered ground is notorious for producing puddles under container-grown plants, allowing *Phytophthora* to increase rapidly.⁶ Even weed cloth can be a problem. With age, sloped gravel beds can settle, forming pockets that collect water or do not rapidly drain.

Many growers tile poorly drained fields to drain off excess water. Tiles generally empty out in a nearby ditch, but if not inspected regularly they can become clogged with debris. Nearby trees such as poplar or willow can fill and clog tiles with their roots. Regular maintenance can help prevent a flooding condition.

Unusual situations also can occur in the greenhouse. Leaks from the roof or a cooling system or internal condensation that drips in the same bench location can start *Phytophthora* problems. Water-ing hoses that are left on the ground or stuck down drain-pipes also can pick up and spread propagules of *Phytophthora*.

Other patterns can include dying plants around irrigation lines and equipment. Leaks, large-volume nozzle sprinkler heads, main line blowouts, or even an oversized drip emitter can result in too much water and problems with *Phytophthora*. Some container nurseries may have sloped, well-drained beds, but drains can clog, back up, and leave plants sitting in several inches of water. Flooded plants may not show symptoms for several months. By that time containers in the bed may have been moved to a different location, masking the original pattern. The plants originally grouped near the drain now may be scattered through a different bed.

Symptoms

Some of the best evidence indicating a *Phytophthora* disease are symptoms shown by the plant itself. Knowledge of the plant's susceptibility is also helpful (see the table Plants Susceptible to Phytophthora Diseases, below).

It is necessary to thoroughly examine above- and belowground parts of the plant. Aboveground symptoms are useful but not completely diagnostic. Many different problems can result in the same aboveground symptoms as Phytophthora root rots. Anything that girdles or cuts off water and nutrients to the top of a plant results in wilting, leaf chlorosis (yellowing), leaf necrosis (browning), and premature leaf fall and plant death. Causes include feeding by root weevil larvae, winter injury, mechanical injury, wire or plastic used to keep trees straight after planting, nursery tags, lack of water, and other fungal root rots as well as Phytophthora root rot.

In Oregon, many plants with Phytophthora root rot do not show aboveground symptoms until summer. As hot, dry weather sets in, the plant does not have enough functional roots left to keep up with transpiration. Plants frequently wilt and collapse within a week. Because of the wilting, many people water plants even more than usual, flooding their roots, encouraging the pathogen, and potentially spreading the disease even more.

Belowground symptoms of Phytophthora root rot include the plant's having few if any feeder roots while the remaining roots are dark and in some stage of decay. Symptoms will be most severe at the root tips and least severe near the root crown. Decaying roots are generally due to other microorganisms' feeding on the roots after being killed by Phytophthora. There are some exceptions, which will be discussed shortly.

Near the advancing margin of a *Phytophthora*-infected root, the roots generally are firm. Use a pocket knife on larger roots (fingernails are okay on smaller roots) to expose the vascular cambium. The area between the bark (phloem) and inner wood (xylem) is highly discolored where the *Phytophthora* organism has been actively colonizing the root or root crown. Many times the cambium has a dull red to reddish brown color. Above this area, the cambium will be the normal color for the plant, generally some shade of white to light green. The transition between the discolored area and the healthy area may be sharp, with a distinctive margin.

Plant Nutrition Diagnosis

JAMES ALTLAND, North Willamette Research and Extension Center, OSU

The only way to accurately diagnose a nutritional problem of plants is to conduct a soil test and tissue analysis at the same time. This identifies which nutrients are deficient (or excessive) in the plant, while determining what factors in the soil may have caused the nutrient imbalance. Visually diagnosing nutrient deficiencies is often inaccurate. Despite the myriad of nutrient deficiency keys found in books and on the Internet, many of the "classic symptoms" of nutrient deficiency look alike. A deficiency symptom can occur because the nutrient is deficient in the soil or because another nutrient is in excess and out-competing the nutrient in question.

An understanding of how plants work and how mineral nutrients behave in the plant will aid your diagnosis of plant nutritional problems. Determining the nutritional status of container crops will also be discussed.

Plant Food

Plants are comprised of roughly 90% water and 10% dry matter but this ratio varies from herbaceous to woody plants. The 10% dry matter consists of 16 elements (Table 1). Plant nutrition should focus on providing the plant the proper environment and fertilizer amendments to achieve the appropriate balance of each element

Contrary to what many fertilizer packages state, fertilizers are not plant food. Plants generate their own food through photosynthesis, in which plants combine carbon, hydrogen, and oxygen by utilizing sunlight as an energy source to form carbohydrates. Plants obtain carbon and oxygen from carbon dioxide (CO₂) in the atmosphere. Plants derive hydrogen and oxygen from water absorbed, primarily through plant roots. Most plants form either starch or sugar for storing energy.

Plants shuttle sucrose (and other carbohydrates) throughout the plant via phloem. Once the sucrose reaches its destination, it can be either stored or converted to energy through metabolic processes. Sugars and starch generated from photosynthesis are plant food. Fertilizers, on the other hand, are mineral nutrients required by the plant for construction and correct functioning of all the biochemical machinery used in photosynthesis as well as cell wall construction, phloem loading, cell division, and other plant biochemical processes. In a gross oversimplification, think of plants as machines that generate their own energy (via photosynthesis), while the mineral nutrients are substances required to coordinate the machinery and keep it running.

Carbon, hydrogen, and oxygen make up roughly 89% of plant dry matter. In greenhouse production carbon can limit plant growth, but in outside crop production it is generally not a factor. Lack of water will cause a host of problems in plants (wilting and death among the most obvious) long before a nutrient deficiency is realized. Thus there are 13 mineral nutrients that are most important when considering plant nutrition.

Mineral Nutrients

Plants require 14 mineral nutrients (Table 1). Six of the mineral nutrients are needed in relatively large quantity and are called **macronutrients**, while the other eight are needed in relatively small quantity and are called **micronutrients**. Examine Table 1 which shows the % dry matter of each nutrient within the plant. Also examine the quantity of each nutrient required in the soil. Some nutrients are required by the plant in greater quantity, and thus need to be present in the soil in greater quantity.

Consider the construction of a barrel and the quantity of water it can hold (Whitcomb, 2001). Imagine that each stave (vertical wooden slat) of the barrel represents one of the 14 mineral nutrients. The concentration of each mineral is represented by the length of its stave, with optimum concentration represented by a stave just long enough for a full barrel. If one of the staves is too short (deficient nutrient) the amount of water that can be held by the barrel is reduced (plant growth is reduced). If one of the staves is too long (nutrient in excess quantity), the barrel can hold no additional water; in fact, some nutrients in excess will cause a deficiency in others. Just as the volume of water the barrel will hold is maximized by each stave being the correct length, plant growth is optimized by each nutrient being in correct concentration in the soil.

Some nutrients are antagonistic with others, that is, their presence in high concentration results in poor absorption of other nutrients. For example, iron and manganese compete for absorption sites, and they may interfere with one another as a cofactor in oxidation-reduction reactions. High concentrations of manganese may manifest itself in the plant as iron deficiency, even if iron is in sufficient quantity in the soil. There are many examples of nutrient antagonism, most of which are a result of competition for absorption and translocation.

Some nutrients are synergistic with others; that is, the presence of one nutrient causes increased uptake of another. Synergistic absorption can be a result of biological factors. For example, calcium is believed to increase phosphorus uptake because it stimulates the transport of phosphorus along mitochondrial membranes. Often, synergistic absorption is a result of one nutrient's effect on rhizosphere pH (the rhizosphere is the soil immediately surrounding the root system). For example, ammonium increases phosphorus uptake in alkaline soils due to its acidifying effect in soil.

Methods of Nutritional Diagnosis

Although useful when confronted with unknown plant problems, visually diagnosing nutrient deficiencies is often inaccurate. If you suspect a nutritional problem, there are two methods for determining the nutritional status of crops. You should conduct a soil test and/or analyze the nutrient concentration of leaf tissue.

Soil tests should be conducted prior to fertilizing field crops. Apply only those nutrients that are indicated by the soil test to be low. For Oregon soils, the best reference currently available is the Oregon State University Extension publication titled "Soil Test Interpretation Guide". Soil tests detail the concentration of most nutrients in the soil, and sometimes this may be good enough to diagnose a problem. However, soil tests will not specifically identify a deficiency within the plant. Only a foliar tissue test can provide this information.

Foliar tissue analyses indicate the current nutrient status within a plant, which nutrients have been adequately absorbed, and perhaps more importantly, which ones have not been absorbed. Sufficiency ranges for each nutrient vary among plant species. The most comprehensive resource for sufficiency ranges in tissue analysis can be found in the book titled "Plant Analysis Handbook II" (Mills and Jones, 1996). Foliar tissue analyses will determine whether a nutrient is deficient in the plant; however, it will not determine why that nutrient is deficient. For example, low iron concentration in foliar tissue may be the result of low iron levels in the soil or high pH (another piece of

Key to Nutrient Deficiencies in Vegetable Crops

Deficiencies producing distinct color changes in foliage.

1. Symptoms first apparent in young leaves.

- a. New leaves develop light-yellow color, first between veins. Later entire leavesc become yellow. Necrosis and dying of tissue usually absent. Usually restricted
- b. Chlorosis appears first between veins or new leaves and then spreads to older leaves. Veins remain green even in advanced stages of deficiency. Chlorotic areas become brown or transparent, and ultimately marked necrosis of affected tissue occurs. Deficiency more general on alkaline or overlimed soils although known on acid soils. Manganese
- c. New leaves abnormally small and mottled with yellow, or uniformly chlorotic. Necrotic, or dead, areas common.....Zinc

2. Symptoms first apparent in old leaves.

- a. First indication, ashen gray-green leaves at base of plant. Leaves develop a bronze and yellowish-brown color. Leaf margins become brown and cup downward. Specks develop along veins of leaf. Tissue deteriorates and dies. Roots poorly developed and brown. Stems slender, become hard and woodyPotassium
- b. Chlorosis first appears between veins of old leaves while veins remain green. Leaves become brittle and margins curl upward. Chlorotic areas turn brown and die. Reddish-purple pigmentation appears instead of chlorosis with some crops. Occurs most frequently on acid soils and on soils receiving high amounts of potassium fertilizer or calcium limestone......Magnesium
- c. Distinctive mottling occurs in older leaves with veins remaining light green. New leaves green at first but become mottled upon expansion. As deficiency is prolonged, puffing of chlorotic areas occur, leaves curl inward, and necrosis sets in along leaf tips and margins......Molybdenum

Deficiencies affecting primarily the growing tissues of roots and stems.

Element Deficient

- 1. Symptoms seldom apparent on older growth.
 - a. Stems thick and woody with vegetative growth retarded. Root tips die and slough off with formation of small bulblike enlargements on remaining tips. New leaves chlorotic while old leaves remain green. New growth lacks turgidity. Terminal buds die in extreme chases. Fruits breakdown at blossom
 - b. New bud leaves and petioles light in color, brittle, and often deformed in shape. Internodes short with rosetting pronounced at shoot terminals. In advanced stages, terminal buds die and new growth develops from buds below. Root growth greatly retarded with dark colored, corky areas forming in bulbous roots of such crops as beets, turnips, and radishes. Hollow stem is a common symptom in cabbage and cauliflower, and cracked stem in celery.....Boron

Deficiencies with localized symptoms.

- 1. Retarded growth with leaf chlorosis.
 - a. Leaves lack turgidity and exhibit a chlorotic condition as if bleached. Growth of entire plant greatly retarded. Host prevalent on soils high in organic matter, and on peats and mucks......Copper
 - b. Retarded growth with stems slender, fibrous and hard. Normal green of leaves fades to solid pattern of yellowish-green. Plant may become entirely yellow in extreme cases. Roots often show greater development than tops in earlier stages of deficiency but finally become stunted, turn brown, and dieNitrogen
 - c. Lower leaves become thick and firm and develop yellowish-green color. Stems are hard, woody, and abnormally elongated and spindly. Root system extensively developed.....Sulfur
- 2. Retarded growth without leaf chlorosis.
 - a. Stems slender and woody. Leaves small and often darker green than normal. With many crops, undersides of leaves develop reddish-purplish cast. Development of fibrous roots greatly restricted. Setting of fruit and maturity delayed Phosphorus

Host and Disease Descriptions

(\mathbb{H} =Homeowner packaging commonly available. \mathbb{Q} = Acceptable in Organic production.)

-A

Abies sp.

See Fir (True)

Acer sp.

See Maple

African Violet (Saintpaulia sp.) — Gray Mold

See also Greenhouse Plants, Ornamental—Gray Mold

Cause *Botrytis cinerea*, a fungus. The disease may become severe when plants are crowded and growing conditions are humid. This fungus readily colonizes senescent leaves and flower parts.

Symptoms Affected parts of the plant become covered with a gray fungus mold. Flowers, leaves, and crowns may be affected. Leaf infection often occurs when withered flowers drop and adhere to the leaves. Infection of the petioles may occur at the point where they come in contact with the pot or other container.

Cultural control

- Avoid crowding plants. Improve ventilation by reducing humidity. Avoid overhead watering.
- 2. Remove and destroy badly affected plants or plant parts.

Chemical control Best when used with cultural controls. Tankmix and/or alternate products with different modes of action to prevent the build-up of resistant fungi.

- 1. Decree 50 WDG at 0.75 to 1.5 lb/A. Do not use more than two (2) sequential applications. 12-hr reentry.
- 2. Exotherm Termil (chlorothalonil) at 1 can/1000 sq ft of greenhouse. It ignites to form a vapor that condenses on the plants. See label for details. 24-hr reentry with no ventilation or 12-hr reentry with ventilation.
- 3. Mancozeb-based products can be used as mixing partners and provides some protection. 24-hr reentry.
 - Fore 80 WP at 1.5 lb/100 gal water plus a spreadersticker.
 - b. Protect DF at 1 to 2 lb/100 gal water plus 2 to 4 oz spreader-sticker.
- 4. Medallion at 2 to 4 oz/100 gal water. Use with oils or adjuvants may cause plant damage. 12-hr reentry.
- 5. Terraguard SC at 4 to 8 fl oz/100 gal water. 12-hr reentry.

Reference Pirone, P.P. 1978. Diseases and Pests of Ornamental Plants, 5th ed. New York: John Wiley & Sons, Inc.

African Violet — Leaf Etch

See also Greenhouse Plants, Ornamental
—Impatiens Necrotic Spot

Symptoms Brown lines occur in concentric patterns around or near the petiole.

African Violet — Nematode (Foliar)

See Begonia-Nematode (Bud and Leaf)

African Violet — Ring Spot (Water Spot)

Cause Occurs when African violets are watered from the top with cold water or when cold water splashes onto leaves.

Symptoms White to yellow ringspots, lines, or arcs develop on the leaves.

Cultural control Water plants from below, and avoid splashing cold water on leaves.

African Violet - Root and Crown Rot

Cause Pythium ultimum, a fungus-like organism that is a common soilborne pathogen. The disease can be severe in overwatered soils or media with poor drainage. It survives unfavorable periods in soil and infected plant debris. Under favorable conditions, such as cooler soil-media temperatures, spores germinate and infect roots. After infection, the fungus-like microorganism spreads mainly in the inner bark tissues of the root and stems. Several spores can persist for several years. Movement of infected plants and/or soil can spread this fungus-like microorganism.

Symptoms Plants suddenly wilt and die. Roots and root crowns become soft and mushy.

Cultural control

- 1. Sterilize rooting media and potting soil before planting.
- Avoid overwatering but keep soil evenly moist by subirrigating. Let plant get dry between waterings when not flowering.
- 3. Destroy diseased plants.
- 4. Fertilize only when plant is beginning to flower.

Chemical control Soil drenches before disease develops. Best used in conjunction with cultural control methods. Rotate fungicides that have a different mode of action for resistant management.

- 1. Banol at 2 to 3 fl oz/10 gal water. 24-hr reentry.
- 2. Banrot 40 WP at 6 to 12 oz/100 gal water. 12-hr reentry.
- 3. Mefenoxam 2 at 0.2 to 1 fl oz/100 gal water as a soil drench. At 0.25 to 1 fl oz/100 gal water at transplanting, and see label for media incorporation. 48-hr reentry.
- 4. Subdue MAXX at 0.5 to 1 oz/100 gal water. No reentry interval.
- 5. Truban 30 WP at 3 to 10 oz/100 gal water. 12-hr reentry.
- 6. Terrazole 35 WP at 3.5 to 10 oz/100 gal water. 12-hr reentry.

Ageratum — Botrytis Blight

See also Greenhouse Plants, Ornamental—Gray Mold

Cause *Botrytis cinerea*, a fungus. The disease may become severe when plants are crowded and growing conditions are humid. This fungus readily colonizes senescent leaves and flower parts.

Symptoms Brown to black spots appear on leaves, stems and flowers which may later coalesce to involve larger areas. Under moist environmental conditions typical gray-brown spore masses of the fungus may appear.

Cultural control

- Avoid crowding plants. Improve ventilation by reducing humidity. Avoid overhead watering.
- 2. Remove and destroy badly affected plants or plant parts.

Chemical control Best when used with cultural controls. Tankmix and/or alternate products with different modes of action to prevent the build-up of resistant fungi.

- 1. 26 GT Fungicide at 1 to 2.5 quarts/A. 12-hr reentry.
- 2. AllBan Flo at 10 to 14.5 fl oz/100 gal water. 12-hr reentry.
- 3. Exotherm Termil at 1 can/1000 sq ft of greenhouse. It ignites to form a vapor that condenses on the plants. See label for details. 24-hr reentry with no ventilation or 12-hr reentry with ventilation.
- 4. Mancozeb-based products can be used as mixing partners and provide some protection. 24-hr reentry.
 - a. Fore 80 WP at 1.5 lb/100 gal water plus a spreadersticker
 - b. Pentathlon DF at 1 to 2 lb/A or per 100 gal water.
 - c. Protect DF at 1 to 2 lb/100 gal water plus 2 to 4 oz spreader-sticker.
- Medallion at 2 to 4 oz/100 gal water. Use with oils or adjuvants may cause plant damage. 12-hr reentry.
- OHP 26 GT-O at 1 to 2.5 quarts/100 gal water. Limit to two
 applications per year to aid resistance management.
 12-hr reentry.
- 7. Terraguard SC at 4 to 8 fl oz/100 gal water. 12-hr reentry.

Ailanthus (Tree of Heaven) — Verticillium Wilt

See Maple - Verticillium Wilt

Ajuga — Botrytis Blight

See also Greenhouse Plants, Ornamental—Gray Mold

Chemical control Best when used with cultural controls. Tankmix and/or alternate products with different modes of action to prevent the build-up of resistant fungi.

- 1. 26 GT Fungicide at 1 to 2.5 quarts/A. 12-hr reentry.
- 2. Decree 50 WDG at 0.75 to 1.5 lb/A. Do not use more than two (2) sequential applications. 12-hr reentry.
- 3. Exotherm Termil at 1 can/1000 sq ft of greenhouse. It ignites to form a vapor that condenses on the plants. Do not use during bloom. See label for details. 24-hr reentry with no ventilation or 12-hr reentry with ventilation.
- OHP 26 GT-O at 1 to 2.5 quarts/100 gal water. Limit to two
 applications per year to aid resistance management.
 12-hr reentry.
- 5. Terraguard SC at 4 to 8 fl oz/100 gal water. 12-hr reentry.

Ajuga — Crown Rot

Cause The fungus *Phoma* sp. has been found in greenhouse grown plants by the OSU Plant Clinic and reported from Georgia. The problem in Georgia was attributed to infected plants coming in from plug production facilities in Central America. Plants die quickly.

Sclerotium rolfsii can also infect crowns and causes a sudden wilting and death but is rarely seen in the PNW.

Symptoms Yellowing, dulling, wilting, and death of plant foliage. Roots had a dark brown discoloration.

Cultural control Sanitation of diseased plants will be the best option as there are no controls once the fungus has infected the plants.

 Inspect plugs as they come in for discolored roots. Discard plants when found.

Reference Williams-Woodward, J. 2005. Pathogenicity of crown rot and root rot disease of *Ajuga reptans* caused by *Phoma* sp. Phytopathology 95:S111

Ajuga — Powdery Mildew

Cause Erysiphe biocellata (formerly Erysiphe cichoracearum) has not been reported formally for the Pacific Northwest, but it is a common problem. This fungus is favored by conditions that produce high humidity but dry leaves. It is a highly specialized pathogen that forms a close association with the host. Conditions that favor the host also favor the pathogen. Much of the fungus remains on the outside of infected plant parts but sends in rootlike structures, haustoria, to obtain nutrients. The white growth seen is composed of both mycelium and fungal spores.

Symptoms Grayish white, powdery spots develop on leaves.

Cultural control

1. Space plants for good air circulation.

Chemical control Fungicides will do best when used before symptoms develop. Few materials have good eradicant activity. Use at 7- to 14-day intervals; using shorter intervals when environmental conditions favor disease development.

- 1. Banner MAXX at 5 to 8 fl oz/100 gal water. Although not listed for this pest, it may be effective. 24-hr reentry.
- Bicarbonate-based products might be used to supplement a normal program when powdery mildew is first observed.
 Do not mix with acidifying agents. Thorough and frequent coverage is essential.
 - a. Armicarb 100 (85% potassium bicarbonate) at 2.5 to 5 lb/100 gal water. 4-hr reentry.
 - MilStop (85% potassium bicarbonate) at 2 to 3 lb/A.
 1-hr reentry.
- 3. Heritage at 1 to 4 oz/100 gal water plus a non-silicone-based wetter sticker. 4-hr reentry.
- 4. Insignia at 4 to 8 oz/100 gal water. Do not use with organosilicate-based adjuvants. Use preventively only. 12-hr reentry.
- 5. Rubigan AS at 3 to 5 fl oz/100 gal water. 12-hr reentry.
- 6. Terraguard SC at 4 to 8 fl oz/100 gal water. Although a 16 oz/100 gal water rate can be used for initial applications to existing infections, use only in conjunction with a regular scouting program that detects initial symptom development. 12-hr reentry.

Alder (Alnus sp.) - Catkin Hypertrophy

Cause Several *Taphrina* sp., fungi. Generally not significant enough a problem to warrant control.

Symptoms Catkin scales enlarge and twist so that they look like reddish, curled tongues. A white, glistening layer of spores may develop on the surface of infected catkins.

Chemical control Applied in the dormant season before buds begin to grow in the spring.

1. Tetrasul 4s5 (27% Lime Sulfur) at 2 gal/100 gal water plus light medium summer oil. Hi-Yield Lime Sulfur Spray is registered for home use. 48-hr reentry. ℍ ロ

Index

A	Agraricales sp. Lawn and Turf—Fairy Ring and	Sclerotinia Crown and Stem Rot 78 Spring Black Stem and Leaf Spot
Abelmoschus sp. Host for Verticillium albo-atrum 37	Mushrooms 306 Agrobacterium radiobacter K84 in Crown Gall Control 44	(Black Stem) 78 Verticillium Wilt 78 Winter Injury 78
Abiotic Wilt Hop 284	Agrobacterium rubi Blackberry—Crown and Cane Gall	Alfalfa Mosaic Alfalfa 75
Abutilon sp. Host for Verticillium albo-atrum 37 Host for Verticillium dahliae 37	124 Crown Gall in Nursery Crops 43	Alfalfa Mosaic Virus 48 Alfalfa—Alfalfa Mosaic 75 Clover—Virus Diseases 185
Aceria tosichella Corn—High Plains Disease 190 Wheat—High Plains Disease 487	Agrobacterium spp. Testing Services 10 Agrobacterium tumefaciens	Pea—Pea Streak 348 Pepper—Virus Diseases 366 Potato—Calico 387
Aceria tulipae Wheat—Wheat Streak Mosaic 495	Apple—Crown Gall 83 Blackberry—Crown and Cane Gall 124	Algae Controlling on Plants 60
Acer sp. (See Maple) Host for Verticillium albo-atrum 37	Blueberry—Crown Gall 130 Cherry—Crown Gall 168 Crown Gall in Nursery Crops 43	Lawn and Turf 302 Alimentary Toxic Aleukia Causes of 36
Acidovorax avenae subsp. cattleyae Orchid—Bacterial Brown Spot 341	Euonymus—Crown Gall 223 Rose—Crown Gall 428	Alkali Yellows Strawberry 449
Acidovorax avenae subsp. Citrulli Watermelon—Bacterial Fruit Blotch/ Seedling Blight 482	Walnut—Crown Gall 480 Agrobacterium vitis (See Rhizobium vitis)	Allantophomopsis cytisporea Cranberry—Fruit Rots 197
Aconitum sp. and Sclerotinia sclerotiorum 39	Crown Gall in Nursery Crops 43 Ailanthus sp.	Allium sp. Field Inspection for White Rot 11
Host for Verticillium albo-atrum 37 Actinidia sp. Host for Verticillium dahliae 37	Host for Verticillium albo-atrum 37 Ajuga	Almond Crown Gall 43
Activators of Plant Defense for Disease Control (table) 499	Botrytis Blight 74 Crown Rot 74 Powdery Mildew 74	Almond Calico Cherry—Prunus Necrotic Ringspot 173
Acyrthosiphon pisum (See Also Pea Aphid) Alfalfa—Alfalfa Mosaic 75 Adjuvants	Albino Cherry—X-Disease 177 Albugo candida Money Plant—White Rust 329	Alternaria alternata and Damping-off 32 Geranium—Alternaria Leaf Spot 239 Pear—Storage Rots 362
Chemical Types 533 in Products 533 pH and Chemical Half-life 535 Spray Tank Buffers 535 Stickers 534 Surfactant Application Rates 534	Radish—White Rust 289, 407 Alder and Phytophthora Diseases 24 Catkin Hypertrophy 74 Leaf Curl 75	Pieris—Leaf Spot 374 Alternaria Black Spot Rapesced 408 Alternaria Blight Zinnia 496
Surfactants 533 Aesculus sp. Host for Verticillium albo-atrum 37	Powdery Mildew 75 Rust 75 Alfalfa	Alternaria brassicae Cabbage and Cauliflower—Black Spot 141
Aflatoxicosis Causes of 36	Alfalfa Mosaic 75 and Phytophthora Diseases 24 and Verticillium Wilt 38	Rapeseed—Alternaria Black Spot 408 Seed Crop, Crucifers—Black Spot (Leaf, Stem, or Pod Spots) 434
African Violet and Verticillium Wilt 38 Gray Mold 73 Leaf Etch 73 Ring Spot (Water Spot) 73	Anthracnose 75 Bacterial Wilt 75 Crown Rot 75 Crown Wart 76 Damping-off 76 Dodder 76	Alternaria brassiciola Cabbage and Cauliflower—Black Spot 141 Seed Crop, Crucifers—Black Spot (Leaf, Stem, or Pod Spots) 434
Root and Crown Rot 73 Agaricus spp. Lawn and Turf—Fairy Ring and Mushrooms 306	Downy Mildew 76 Host for Parasitic Plants 54, 55 Leaf Spots and Blotches 77	Alternaria cucumerina Cantaloupe—Alternaria Leaf Blight 149 Cucumber—Alternaria Leaf Spot 201
Ageratum and Verticillium Wilt 38 Botrytis Blight 73	Nematode (Bulb and Stem) 77 Nematode (Lesion) 77 Nematode (Root-knot) 77 Phytophthora Root Rot 78	Squash—Alternaria Leaf Blight 443 Squash—Storage Rots 447 Alternaria dauci Carrot—Leaf Blight 153

Carrot-Leaf Blight 153